Science of the Total Environment 584–585 (2017) 48–54

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Richness, coverage and concentration of heavy metals in vascular epiphytes along an urbanization gradient

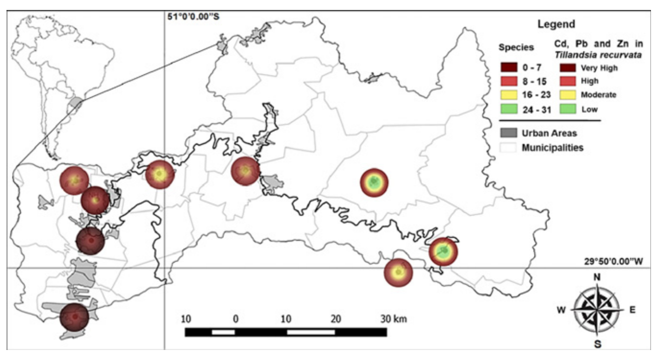
Diego Fedrizzi Petry Becker [a,*], Rafael Linden [b], Jairo Lizandro Schmitt [a]

[a] Laboratório de Botânica, Universidade Feevale, ERS-239, 2755 Novo Hamburgo, Rio Grande do Sul, Brazil
[b] Laboratório de Toxicologia, Universidade Feevale, ERS-239, 2755 Novo Hamburgo, Rio Grande do Sul, Brazil

HIGHLIGHTS

- Concentration of metallic elements strongly associated with the vehicular fleet
- Epiphyte richness and coverage affected along an urbanization gradient
- Lower epiphytic diversity in sites with heavier metal concentration

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 25 July 2016
Received in revised form 13 January 2017
Accepted 14 January 2017
Available online 27 January 2017

Editor: D. Barcelo

Keywords:
Bioindicators
Air quality
Urbanization

ABSTRACT

Richness, coverage and concentration of heavy metals in vascular epiphytes were analyzed in isolated trees along an urbanization gradient in Southern Brazil. A total of 20 phorophytes were sampled in the main street of each site. Concentrations of chromium, cadmium, lead, manganese, nickel and zinc were measured in the leaves of *Tillandsia recurvata* L. using Graphite Furnace Atomic Absorption Spectrophotometry. A decreasing gradient of epiphyte richness and coverage was observed as urbanization increased. Vehicle fleet and demographic density were the parameters most correlated with the reduction of epiphytic diversity. In *T. recurvata*, significantly higher values of cadmium, lead and zinc were recorded in the most urbanized areas, and were strongly related to the vehicle fleet and to the demographic density in these sites. The results demonstrated that these parameters could be applied to the diagnosis of environmental quality in urban areas, allowing standardized analyses in other regions.

1. Introduction

The intense substitution of natural environments for urban, industrial and agricultural areas has caused a series of changes in the planet environmental conditions, affecting air, water and soil quality (Uttara et al., 2012). Studies in urban areas are extremely relevant, given that they represent 4% of the world's surface and 54% of its

* Corresponding author.
E-mail addresses: biologo.db@gmail.com (D.F.P. Becker), rafael.linden@feevale.br (R. Linden), jairols@feevale.br (J.L. Schmitt).

http://dx.doi.org/10.1016/j.scitotenv.2017.01.092

population (United Nations, 2015). These areas are important sources of pollution and may have many different microclimatic conditions (Ncar, 2011). The Rio dos Sinos watershed, located in southern Brazil, is one of the most polluted in the country and is also part of the Atlantic Forest Biome, an important global hotspot for conservation (Hudson et al., 2014).

Vascular epiphytes are a plant group that depends on arboreal and arborescent species, the phorophytes, for mechanical support (Benzing, 1990). Epiphytic diversity is associated with microclimatic factors such as humidity and luminosity, and substrate characteristics (Wagner et al., 2015). Phorophytes can exhibit external morphological variations (Zotz and Andrade, 2002), differences in height, diameter (Mehltreter et al., 2005) and in the physicochemical properties of the bark, such as moisture and pH (Johansson, 1974; Mehltreter et al., 2005). Moreover, richness and epiphytic abundance may indicate anthropic disturbance, once they respond to environmental changes in a short period of time (Werner, 2011).

Atmospheric pollution, which has direct effect on human health and biodiversity, is currently related to seven million deaths worldwide, and is one of the primary causes of species extinction (Dudley and Stolton, 1996; WHO, 2014). In general, urban pollution originates in vehicular traffic and industrial activities (Sokhi and Kitwiroon, 2008). Among the pollutants released, heavy metals and polycyclic aromatic hydrocarbons (PAH) have attracted attention due to their toxic effects, being considered extremely harmful to human health and to the environment (Hinwood and Di Marco, 2002; Järup, 2003; Tchounwou et al., 2012).

Plant organisms have been used in active and passive biomonitoring analyses (Figueiredo et al., 2006; Kono et al., 2012; Simon et al., 2014; Vuković et al., 2015). The use of widely distributed passive biological indicators makes it possible to assess the synergetic effects of pollution and environmental conditions on individuals across a wide spatial scale and at a relatively low cost (Gorecki and Namiesnik, 2002). In this regard, vascular epiphytic flora exhibits anatomical and physiological adaptations that enable them to absorb elements directly from the atmospheric humidity (Kress, 1986). These features allow some species to be used as models in environmental diagnoses, as *Tillandsia* L., which is one of the most widely used (Abril et al., 2014; Bermudez et al., 2009; Miranda et al., 2016; Santos et al., 2013; Wannaz et al., 2006).

High concentrations of heavy metals in *Tillandsia recurvata* L. have been associated with vehicular traffic (Bermudez et al., 2009; Santos et al., 2013). This species is abundant in urban areas in the Rio dos Sinos Hydrographic Basin (Becker et al., 2015a), which allows a passive diagnosis of air quality across different degrees of anthropic disturbance.

The diagnosis of epiphytic diversity, passive analysis of heavy metals in *Tillandsia recurvata* and their possible relationship with anthropic characteristics allows an integrated assessment of environmental quality along an urbanization gradient. Thus, the aim of this study was to determine epiphyte richness, coverage and concentration of heavy metals in *Tillandsia recurvata* in sites showing different degrees of urbanization. The hypotheses tested were that: (I) epiphyte richness and coverage decrease and the concentration of heavy metals increases in *T. recurvata* as urbanization grows; and (II) the richness and coverage of epiphytes are more related with the degree of urbanization than with the phorophyte characteristics of each area.

2. Material and methods

2.1. Study area

The Rio dos Sinos watershed, located in the state of Rio Grande do Sul, Brazil, encompasses 32 municipalities in an area of 3820 km^2, with 1,343,558 inhabitants, of which approximately 94% are urban dwellers and 6% are rural residents (IBGE, 2015). Its territory is divided into upper, middle and lower stretches.

The study was performed at nine sites representing different levels of urbanization (rural, urban plus urban and industrial) along the Rio dos Sinos watershed, at least 5 km away from each other (Table 1). The rural sites were located in the upper stretch and present lower vehicular traffic, lower degree of urbanization, lower genotoxic air (Cassanego et al., 2015) and the most conserved areas (Rocha-Uriartt et al., 2015). Urban sites were located in the middle stretch, between the rural and the urban and industrial areas, with intermediate degree of urbanization and vehicular traffic. The urban and industrial sites were located in the lower stretch and have higher vehicular traffic, most industrialized activities, besides higher percentual of urbanization (FEPAM, 2014; IBGE, 2015). Studies showed that Caraá site is the most conserved area of the region and presents lower air genotoxicity (Cassanego et al., 2015; Rocha-Uriartt et al., 2015).

According to the Köppen classification system, the climate in the region is classified as Cfa (humid subtropical) (Peel et al., 2007), that is, humid mesothermal climate, with well-defined summers and winters, and rainfall throughout the year. The average temperature in the hottest month is greater than or equal to 22 °C and above 10 °C in the coldest month, characterizing mild winters.

In the rural sites, average annual temperature in 2014 was 19.1 °C and total rainfall was 3058 mm. In the urban sites, average temperature in the same year was 21.6 °C, while annual rainfall was 1642 mm (Faccat, 2015). In the urban and industrial sites, average temperature and total rainfall in 2014 were 20.8 °C and 1981 mm, respectively.

2.2. Heavy metal content

At each site, passive analyses were performed to assess chromium (Cr), cadmium (Cd), lead (Pb), manganese (Mn), nickel (Ni) and zinc (Zn) concentrations in *Tillandsia recurvata* L. In 2015, mature leaves were collected between 1 and 2 m above the ground (Kono and Tomiyasu, 2009; Sutton et al., 2014), with three collections in each municipality, making a total of 27 samples (Boaretto et al., 2009). The leaves were packaged separately and washed under running water followed by distilled water to remove substances from the surface. Then, the samples were oven dried at 70 °C for 72 h. The dry material

Table 1
Population, percentage of urban inhabitants (Urban), demographic density (Dens.), vehicular fleet (Fleet) and main surrounding matrix (Matrix) of sites and their respective stretches in the Rio dos Sinos Hydrographic Basin, State of Rio Grande do Sul, Brazil.
Source: IBGE (2015)

Matrix	Site	Population	Urban. (%)	Dens. (Inhab. km^2)	Fleet	Stretch
Rural	Caraá (29°47′26,3″S; 50°26′01,03″W – alt. 44 m)	7,312	14.5	24.8	2,484	Upper
	Rolante (29°39′06,09″S; 50°34′33,31″W – alt. 45 m)	19,485	78.6	64.2	10,663	
Urban	Santo Antônio da Patrulha (29°50′01,57″S; 50°31′35,68″W – alt. 47 m)	39,685	70.8	37.8	22,143	Middle
	Parobé (29°37′46,35″S; 50°49′57,53″W – alt. 52 m)	51,502	94.4	474.0	25,840	
	Sapiranga (29°38′11,02″S; 51°00′22,25″W – alt. 32 m)	74,985	96.4	542.1	42,500	
Urban and industrial	Estância Velha (29°39′6,82″S; 51°10′21,05″W – alt. 45 m)	42,574	97.4	816.4	26,485	Lower
	Novo Hamburgo (29°41′16,28″S; 51°7′47,92″W – alt. 29 m)	238,940	98.3	1067.6	147,713	
	São Leopoldo (29°46′12,51″S; 51°8′29,88″W – alt. 15 m)	214,087	99.6	2083.8	104,104	
	Canoas (29°55′24,45″S; 51°10′26,09″W – alt. 15 m)	323,827	100.0	2470.2	176,288	